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FACTORS AFFECTING THE TRAPPING OF MALES OF *SPODOPTERA FRUGIPERDA* (LEPIDOPTERA: NOCTUIDAE) WITH PHEROMONES IN MEXICO

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ABSTRACT

Four commercial sex pheromones and virgin females were tested as attractants for male fall armyworm (FAW), *Spodoptera frugiperda* with Scentry *Heliothis* traps in sorghum fields in Chiapas, Mexico. We observed significant differences among the lures tested. Pherotech, virgin females, and Scentry lures elicited different responses from Chemtica and Trece lures. In another experiment performed in Michoacán, Mexico, we found that Scentry *Heliothis* traps baited with Chemtica lures placed at 1.5 m above ground caught significantly more males than traps placed at a height of 2 m. In contrast, the capture of *S. frugiperda* males with bucket traps placed at 1 m height was not significantly different from that of traps placed at 1.5 and 2 m height. When baited with pheromone, Scentry *Heliothis* traps caught more non-target insects than bucket traps. Apidae was the most prevalent family of non-target insects caught in both experiments.

Key Words: *Spodoptera frugiperda*, trapping, pheromones, Mexico, non-target insects.

RESUMEN

Se evaluaron cuatro feromonas comerciales y hembras vírgenes como atrayentes contra el gusano cogollero *Spodoptera frugiperda* usando trampas tipo *Heliothis* en un campo de sorgo en Chiapas. Las capturas de los machos con las feromonas comerciales Chemtica y Trece fueron significativamente diferentes a las capturas obtenidas con las feromonas Pherotech, Scentry y hembras vírgenes. En otro ensayo realizado en el Estado de Michoacán, México, encontramos que las capturas obtenidas con las trampas tipo *Heliothis* cebadas con feromona de Chemtica y colocadas a una altura de 1.5 m arriba del suelo, fueron significativamente mejores que las capturas de las trampas colocadas a 2 m. Por lo contrario, las capturas obtenidas con las trampas bucket colocadas a 1 m de altura fueron muy similares a las de las trampas colocadas a 1.5 m y 2 m. Las capturas de la entomofauna asociada fueron mucho mayores en las trampas tipo *Heliothis* que las obtenidas con las trampas bucket, siendo Apidae la familia más abundante.

Translation provided by authors.

The fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), is a major pest of corn, rice, and forage grass (Pashley 1989), and is found in almost all parts of Mexico with the greatest damage occurring in the Southern and Eastern tropical States (Andrews 1980). Control of *S. frugiperda* in maize is achieved by application of methyl parathion, chlorpyrifos, methamidophos, and phoxim, among others insecticides. There are a number of problems related to the habitual use of synthetic pesticides including detrimental effects on the health of farm workers in rural communities in Latin America (McConnell & Hruska 1993; Tinoco & Halperin 1998). For this reason, additional methods of control are desirable for development of a safe system of integrated pest management in the field, including the use of pheromones. Lepidopteran pheromones have been used for insect monitoring, mass trapping, and mating disruption of a great diversity of insect pests (Wyatt 1998). The female-produced sex pheromone of *S. frugiperda*, which is commercially available, has been shown to be a useful tool for monitoring male populations (Adams et al. 1989; Mitchell et al. 1989; Lopez et al. 1990; Gross & Carpenter 1991; Weber & Ferro 1991). However, commercial sex pheromones lures made in Great Britain and USA can give erratic capture rates in Mexico and Central America (Andrade et al. 2000; Malo et al. 2001).

The population of adult male *S. frugiperda* is frequently monitored with plastic funnel traps (Universal Moth Traps or "bucket" traps or Unitraps) baited with sex pheromones components as lures (Mitchell et al. 1985; Tumlinson et al. 1986). However, this type of trap gave poor results when tested in the coastal plain of Chiapas, Mexico (Malo et al. 2001). Many of the parameters for monitoring FAW with sex pheromone traps have already been described (Mitchell et al. 1985; Mitchell et al. 1989; Pair et al. 1989). However, there exists the possibility that these parameters may differ from one region to another. It is therefore necessary to determine the trap and commercial sex pheromone combination most appropriate for use in southern Mexico. For example, two FAW strains have been reported in Mexico, which are believed to be due to reproductive isolation of the populations arising from geographical isolation (Lopez-Edwards et al. 1999). In this study, we tested a selection of commercial lures. We also report the evaluation of the height of traps placed in the field and three designs of traps with Chemtica lures. These experiments were made in the states of Chiapas and Michoacán, two of the most important maize growing states in Mexico.

Materials and Methods

Chiapas Trial

The first trial was performed at El Manzano in the municipality of Tapachula (14°44'N, 92°19'W, altitude 20 m above sea level), Chiapas, Mexico, in a field planted with sorghum at 20 days post-planting. This area has a humid tropical climate with heavy rain in the summer, with an average annual rainfall of 2,063 mm. The average annual temperature is 26°C, with April and May being the warmest months. Two crop cycles are grown annually in El Manzano; sorghum or maize from January to May, watered by sprinkler irrigation, and soybean during the rainy season from July to October.

Four commercial sex pheromone lures and virgin females as controls were evaluated in a fully randomized plot design with three replicates of each treatment. The replicate plots were arranged in parallel lines approximately 30 m apart in a field planted with sorghum (10 ha). The traps were placed at height of 1.5 m. Lures tested were Scentry (Scentry, Inc., Buckeye, AZ), a gray rubber septum dispenser; Trece (Trece, Inc., Salinas, CA) a red rubber septum dispenser, obtained through Gempler's, Inc. (Belleville, WI); Chemtica, a bubble cup (Chemtica, Heredia, Costa Rica); Pherotech, a red rubber septum dispenser (Pherotech, Delta, BC, Canada) and a virgin female (from the laboratory colony) used as control. The traps used were the Scentry *Heliothis* trap, which is a white double cone collapsible plastic net (Ecogen, Inc., Billings, MT). The traps were placed on 10 February 2001 and they remained in place for one week. The trap captures were recorded daily from 11 to 16 February, a total of 6 observation dates. The virgin female was checked daily and replaced when necessary. On each date, we emptied the traps and recorded the number of *S. frugiperda* males. All non-target insects captured were identified to order (Borror et al. 1989). Voucher specimens were placed in the insect collection held at El Colegio de la Frontera Sur, Tapachula, Chiapas, Mexico.

Michoacán Trial

The second trial was performed in Apatzingán (19°02'N, 102°02'W), Michoacán, Mexico, from 29 July to 26 September, 2001. Apatzingán is at an altitude of 320 m above sea level with a tropical dry climate. Two varieties of maize (V454 and V455) were grown here, at the usual density of 50,000 plants/ha with 80 cm row spacing. A two-factor design was used in the experiment. Two types of traps were used, Scentry *Heliothis* trap and a green reusable bucket trap (Gempler's). The traps were placed at heights of 1, 1.5, and 2 m above the ground. Traps were hung on wooden stakes placed at 30-m intervals along planted rows. We used a bubble cup, commercial sex pheromone from Chemtica. The treatments were arranged in a fully randomized plot design with four replicates of each treatment. All lures were changed monthly. Trap captures were recorded every 3-4 d, and the treatments were rotated after each observation date. On each date, we emptied the traps and recorded the numbers of FAW males and non-target insects captured. All non-target insects captured were identified to family (Borror et al. 1989). Voucher specimens were placed in the insect collection held at Centro Nacional de Investigaciones para la Produccion Sostenible (CENAPROS), Morelia, Mexico.

At the same time that the traps baited with pheromone were being checked, evidence of feeding damage produced by FAW larvae was evaluated in 100 plants chosen at random within the area of trapping. Typically, larvae stay in the whorl, feeding on new leaves, so the damage to the newly expanding leaves and the presence of frass is easily detected by visual examination of the whorls.

Statistical Analysis

The numbers of male FAW captured per trap per sample period were converted to percentages of the total number of moths captured by each trap and lure within each plot (Mitchell et al.

1985). Percentage values were arcsine transformed to increase the homogeneity of variance and normality. Results of the experiment to test lures were analyzed by one-way ANOVA and results of the traps placed at different heights were analyzed by two-way ANOVA (trap × height). Treatment means were compared with the Tukey test (P = 0.05). The number of non-target insects caught with the lures in the Chiapas State trial was analyzed as a randomization test (Manly 1994). The effects of trap and height on the families of non-target insects caught at prevalence above 5% in Michoacán State were analyzed by a contingency table involving 2 (traps) × 3 (heights) × 7 (insect families) in the GLIM program (Generalized Linear Interactive Modeling, Numerical Algorithms Group, 1993) in a log-linear model.

Results

Chiapas Trial

The total capture of *S. frugiperda* males for all traps pooled throughout the 6 days was 727. There were significant differences among lures tested (F = 12.5, df = 5,25, P < 0.01). Chemtica and Trece lures elicited a greater capture than virgin females, Scentry, or Pherotech lures (Fig. 1). A very low number of non-target insects (n = 64) were captured during the period of trapping, mainly Apidae (bees), representing 64% of the total non-target insects caught. Other orders captured were Coleoptera, Lepidoptera, and Hymenoptera. No significant differences were detected in non-target insects caught in relation to the lures used in a randomization test (P > 0.05). Chemtica and virgin females were the lures that attracted the greatest number of non-target insects caught (32 and 31%, respectively). Trece, Scentry, and Pherotech lures captured 20.3%, 14%, and 1.5%, respectively.

Michoacán Trial

The total capture of *S. frugiperda* males was 2397. Of the total number of males captured, 81.1% were caught with the Scentry *Heliothis* trap and 18.9% with bucket traps. The efficiency of Scentry *Heliothis* traps was affected by height, whereas the catch of bucket traps was independent of height, resulting in a significant interaction effect (F = 4.3; df = 2,15; P = 0.03) (Fig. 2).

The number of insects caught with pheromone traps (Scentry *Heliothis* and bucket traps placed at different heights) as well as the feeding damage produced by *S. frugiperda* larvae on the plants was generally higher at the start of the study, but at the end of the first month, the population and the feeding damaged produced by FAW larvae had decreased (Fig. 3). Great variation was observed in the number of insects caught over time and in the feeding damage resulting from the FAW infestation. In this experiment, no chemical insecticide was used to control FAW.

A total of 2352 non-target insects was caught with both traps (Scentry and bucket) during the trial period. Significant differences were observed among the number of non-target insects at the level of family (χ^2 = 488, df = 5, P < 0.01). The most abundant non-target insects caught were Apidae, followed by Cicadellidae and Tachinidae (Fig. 4). Scentry *Heliothis* traps caught a total of 2000 non-target insects, whereas bucket traps caught 352. Apidae was the most prevalent group caught

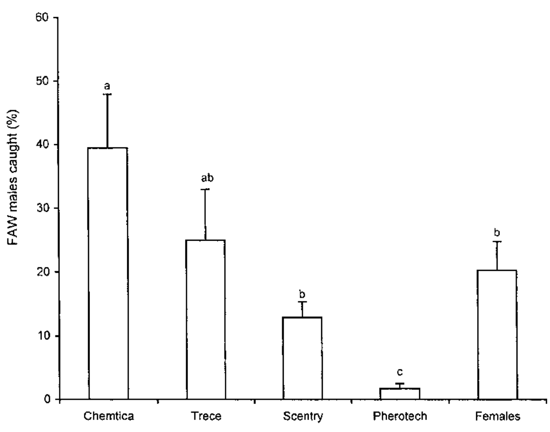

Fig. 1. Percent capture of male fall armyworm (+SEM) with Scentry traps baited with commercial lures in a sorghum field in Chiapas State, Mexico. Significant differences within traps and height are shown by different letters over the bars (Tukey test, P = 0.05).

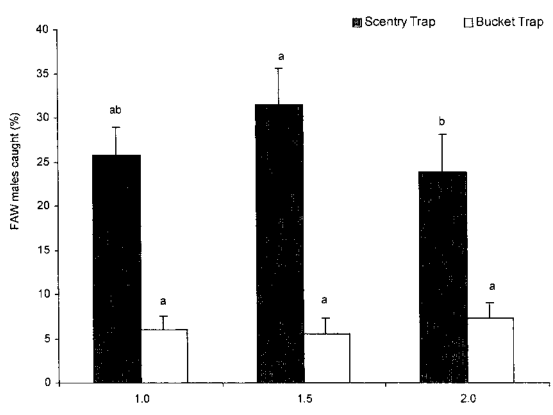

Fig. 2. Percent capture of male fall armyworm (+SEM) with Scentry and bucket traps baited with Chemtica lures and placed at different heights (mm) in a maize field in Michoacán State, Mexico. Significant differences within traps and height are shown by different letters over the bars (Tukey test, P = 0.05).

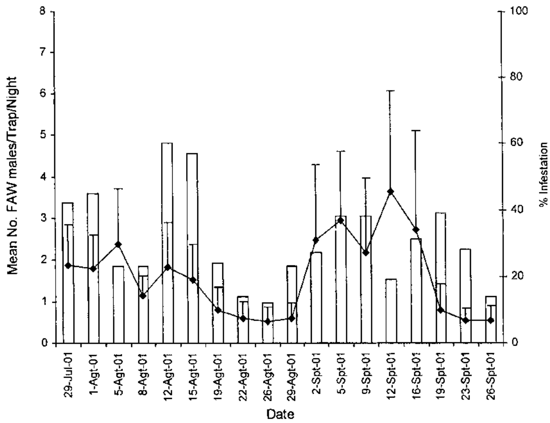

Fig. 3. Seasonal mean number (+SEM) of male *Spodoptera frugiperda* caught with sex pheromone traps in a maize field in Michoacán, Mexico, is in line. Percentage of feeding damage produced by *S. frugiperda* at each observation date is in column.

with Scentry *Heliothis* traps and Carabidae with bucket traps. Carabidae, caught most with bucket traps, was not included in the analysis of the effects of trap and height because few were caught in Scentry *Heliothis* traps. Scentry *Heliothis* traps placed at 1 m height caught a total of 910 non-target insects, whereas traps placed at 1.5 m caught 649 non-target insects and traps placed at 2 m caught 441 non-target insects. Bucket traps placed at 1 m caught a total of 105 non-target insects, traps placed at 1.5 m caught a total of 139 non-target insects and traps placed at 2 m caught a total of 108. Overdispersion was observed in the distribution of data on the non-target insect families and different traps placed at different heights. Overdispersion was corrected by the methods described by Hinkley et al. (1990). No significant interaction was detected among trap type and height of traps (χ^2 = 9.98, df = 14, P = 0.76), indicating that the number of non-target insects caught in the traps was independent of the height at which the trap was placed. However, a significant interaction was observed between

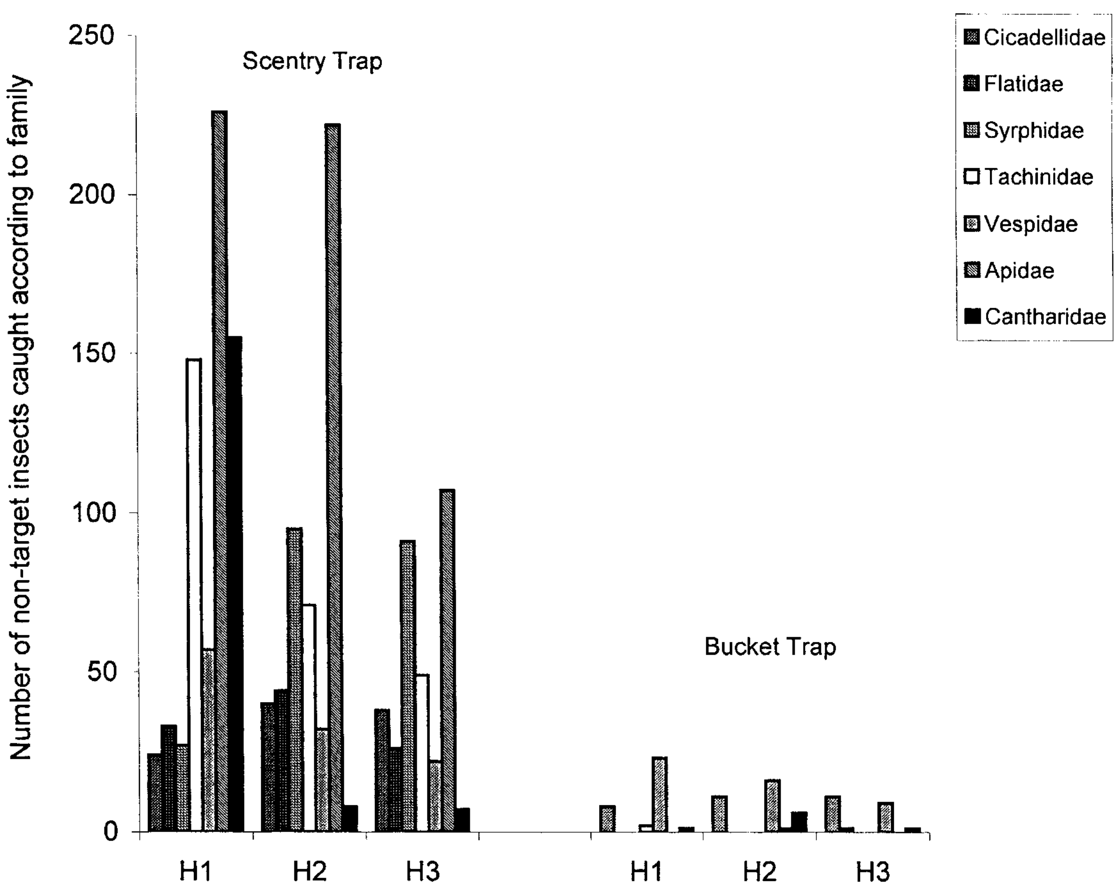

Fig. 4. Number of each non-target insect family caught with Scentry and bucket traps in a maize field in Michoacán State, Mexico. H1 = 1 m, H2 = 1.5 m, and H3 = 2 m height at which traps were placed.

family × type of trap × height of trap indicating that each family of non-target insects responded differently to trap type and height (Table 1).

Discussion

From the results of the commercial lures tested it is clear that the Chemtica and Trece lures can be used for monitoring *S. frugiperda* males in Mexico. Scentry *Heliothis* traps baited with Chemtica lures placed at 1.5 m above ground caught significantly more *S. frugiperda* males than traps placed at a height of 2 m. In contrast, capture with bucket traps was not affected by trap height. The parameters for monitoring FAW males with pheromone traps have been described in studies performed in Florida, USA (Mitchell et al. 1985; 1989; Pair et al. 1989). The results obtained in Florida and the results in Mexico are not markedly different. Trap height is one of the most important aspects of trap deployment, along with trap density and the position of the trap with respect to vegetation (Wall 1989).

Hartstack screenwire cone traps and plastic funnel traps were reported to capture more moths than sticky and electric grid traps (Tingle & Mitchell 1975; Mitchell et al. 1985). However, when the population density of FAW was low, both types of trap designs tested did equally well in capturing *S. frugiperda* males (Mitchell et al. 1985; Adams et al. 1989; Pair et al. 1989). For higher density populations, Hartstack traps generally performed better than unitraps (Mitchell et al. 1985; Pair et al. 1989). Green traps were only minimally attractive when baited with FAW pheromone and insecticide (Gross & Carpenter 1991). Similar results were reported by Malo et al. (2001) in the evaluation of commercial lures and traps; green traps caught a low number of FAW males in the coastal plain of Chiapas, Mexico. Trap color has been reported to be influential to the capture of several noctuids, including *S. frugiperda*. Plastic bucket traps with green canopies, yellow funnels, and white bucket traps collected more *Spodoptera* spp. males than all-green traps in several studies (Mitchell et al. 1989; Pair et al. 1989; Lopez 1998). However, Meagher (2001a) reported that more moths were captured in these standard traps than all-white or all-green traps, as was also reported with *S. exigua* (Lopez 1998). It was suggested that a possible factor responsible for low rates of capture of moths in green traps was the low reflectance at wavelengths where moth vision is most sensitive (Mitchell et al. 1989).

In this study, we caught very few non-target insects in the trial conducted in Chiapas in traps baited with pheromone. In contrast, in the Michoacán trail, the number of FAW males caught with pheromone traps was similar to the number of non-target insects. However, the presence of honeybees, *Apis mellifera* L., was evident in both trials. The fact that bees were caught in both traps also elevated the apparent number of captures (Fig. 4), although bee captures were more common in Scentry *Heliothis* traps. It is possible that a few species of non-target moths may be attracted by certain chemical components of the pheromone of *S. frugiperda*. Weber and Ferro (1991) reported that noctuids *Leucania phragmitidicola* Guenée, *Sideridis rosea* (Harvey) and *Eurois occulta* (L.) were commonly caught in FAW traps in Massachusetts, USA. Others have also reported that baited traps attract non-target and even beneficial insects (Adams et al. 1989; Mitchell et al. 1989; Gauthier et al. 1991; Gross & Carpenter 1991; Meagher & Mitchell 2001; Malo et al. 2001; Meagher 2001a,b). Apparently trap color may play a role in the attraction of the insects, for example white or yellow traps can attract large number of *Bombus* spp. (Hamilton et al. 1971; Mitchell et al. 1989).

In conclusion, Scentry *Heliothis* traps with a Chemtica and Trece lures gave good results for monitoring FAW males in Chiapas, Mexico. Parts of these results were reconfirmed in Michoacán, Mexico and suggest that the traps are best placed at a height of 1.5 m. However, these traps caught a considerable number of non-target insects and

Table 1. Test of significance of the factors involved in a log-linear model of trap design, trap height, and family of non-target insects caught.

Source of variation	χ^2	*df*	*P*
Trap	591.5	19	<0.001
Height	188.4	20	<0.001
Family	301.0	24	<0.001
Trap-Height	9.98	14	0.76
Trap-Family	78.2	12	<0.001
Height-Family	97.8	28	<0.001

Trap used: Scentry type *Heliothis* and bucket.
Height at which traps were placed: 1, 1.5, and 2 m.
Family of non-target insects caught above 5%: Cicadellidae, Flatidae, Syrphidae, Tachinidae, Vespidae, Apidae, and Cantharidae.
Analysis performed in GLIM with Poisson error distribution corrected for overdispersion.

it is possible that one of the chemical compounds from pheromones or the color of the trap may be involved in the attraction of non-target insects.

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